WE CLAIM

1. An optical amplifier for a wavelength switched optical network comprising:

a Raman module for amplifying a WDM optical signal with a Raman gain;

an EDFA module connected to said Raman module for further amplifying said WDM signal with a EDFA gain; and

a shelf-level control network for monitoring and controlling operation of said optical amplifier to maintain a substantially similar power for all channels of said WDM signal.

2. An optical amplifier as claimed in claim 1, wherein said shelf level network comprises:

an shelf processor for determining a gain target for said optical amplifier based on current performance, topology and connectivity data concerning said wavelength switched network; and

an embedded controller on each card-pack of said modules for dynamically adjusting respectively said Raman gain and said EDFA gain according to said target gain.

3. An optical amplifier as claimed in claim 2, wherein said embedded controller comprises:

a bridge for distributing and collecting an optical trace signal provided between a host card-pack and all card-packs physically connected to said host card-pack;

an interface for connecting said embedded controller with said shelf processor; and

a microprocessor for controlling operation of optical components on said host card-pack.

4. An optical amplifier as claimed in claim 2, wherein said EDFA module has a first and a second stage with a mid-stage access between said first and second stage.

5. An optical amplifier as claimed in claim 4, wherein said embedded controller of said EDFA module comprises a gain control loop which operates each of said stages according to a gain target.

6. An optical amplifier as claimed in claim 2, wherein said Raman module comprises at least two Raman pumps.

7. An optical amplifier as claimed in claim 8, wherein said embedded controller of said Raman module changes the ratio between the power of said Raman pumps for optimizing OSNR performance of said optical amplifier.

8. An optical amplifier as claimed in claim 2, wherein said embedded controller of said Raman module sets said Raman gain to an optimized value based on a attainable maximum Raman gain and the loss of the fiber span upstream from said optical amplifier.

9. An optical amplifier as claimed in claim 1, further comprising a multi-port optical spectrum analyzer module for measuring power and spectrum of said WDM signal in a plurality of measurement points provided on said optical amplifier and transmitting the measurements to said shelf processor over said shelf-level control network.

10. An optical amplifier as claimed in claim 4, further comprising a gain flattening module connected between the stages of said EDFA module to flatten-out the power of specific channels.

11. An optical amplifier as claimed in claim 4, further comprising a dispersion compensating module DCM connected between the stages of said EDFA module, said DCM including a compensator with a net dispersion value and slope selected according to a link target.

12. An optical amplifier as claimed in claim 2, wherein said shelf processor receives identification data from all card packs of said optical amplifier over said shelf-level control network and communicates shelf identity and presence data to a network services controller over a site-level control network.

13. An optical amplifier as claimed in claim 12, wherein, whenever a fiber span preceding said optical amplifier has a low loss, said network services controller operates said Raman pump monitor to maintain a constant net gain.

14. An optical amplifier as claimed in claim 4, further comprising a variable optical attenuator connected between said first and said second stages.

15. A line amplification system for a wavelength switched optical network comprising:

at a first flexibility site, a post-amplifier unit for amplifying a WDM optical signal and launching same over a fiber link;

at a second flexibility site, a pre-amplifier unit for amplifying said WDM optical signal received over said fiber link;

one or more line amplifier units connected on said fiber link between said first and second flexibility sites for amplifying said WDM signal; and

a line monitoring and control system for collecting a plurality of real-time operational parameters pertinent to the current operation of said units and operating said line amplification system according to a plurality of target operational parameters,

wherein said real-time operational parameters change due to end-to-end network churn caused by dynamic set-up and tear-down of user connections.

16. A line amplification system as claimed in claim 15, wherein said line monitoring and control system comprises:

a shelf-level control layer comprising a plurality of shelf-level control networks, each for controlling operation of one or more card-packs of an associate unit; and

a link-level control layer comprising a line-level control network for coordinating operation of said line amplification system to maintain a substantially similar output power for all channels of said WDM signal.

17. A line amplification system as claimed in claim 16, wherein said shelf-level control network comprises:

a shelf processor for providing all optical components on said card-packs with a local address;

a plurality of embedded controllers, each provided on a card-pack; and

an interface between said shelf processor and said embedded controllers for transmitting from said embedded controller to said shelf processor at least optical device specification and measurement data, and transmitting from said shelf processor to each said embedded controller device control data.

18. A line amplification system as claimed in claim 16, wherein said link-level control network comprises:

a network connection controller for providing all shelf processors of said line amplification system with a local address; and

an interface between said network connection controller and all said shelf processors for transmitting from said shelf processors to said network connection controller at least unit and fiber specification and measurement data, and transmitting from said network connection controller to said shelf processors unit control data.

19. A line monitoring and control system for a line amplification system of a wavelength switched optical network comprising:

an embedded control layer, comprising an embedded controller provided on each card pack of an optical amplifier for controlling operation of said card pack;

a link control layer comprising a plurality of shelf processors for coordinating operation of all optical amplifiers connected on a link of said wavelength switched optical network to achieve an output power profile target for said link; and

a network control layer comprising a plurality of optical link controllers for coordinating operation of all optical modules placed on a plurality of consecutive links making-up a connection.

20. A line monitoring and control system as claimed in claim 19, wherein said embedded controllers of all card-packs of an optical amplifier placed in a shelf are connected with an associated shelf processor of said plurality of shelf processors over a shelf LAN.

21. A line monitoring and control system as claimed in claim 19, wherein said shelf processors of all optical amplifiers connected along said link are connected with an associated optical link controller of said plurality of optical link controllers over a link LAN, said optical link controller for at least commissioning and certifying said link and testing link quality parameters.

22. A line management and control system as claimed in claim 19, wherein said optical link controllers of all optical units along an optical path are connected with an associated network connection controller NCC over a path LAN, said NCC for setting-up, tearing-down and controlling said connection.

23. A line monitoring and control system as claimed in claim 19, wherein said embedded controllers and said associated shelf processor distinguish

between operation of said optical amplifier in a normal mode, a power railing mode and a failure mode, for allowing operation at a gain target value above a specified maximum gain value, on demand.

24. An optical amplifier as claimed in claim 23, wherein said link control layer increases said gain target of a downstream amplifier of said line amplification system whenever an amplifier operates in said power railing mode.

25. An optical amplifier as claimed in claim 18, wherein said optical link controller instructs an optical amplifier connected in said link to provide a gain target for an upstream optical amplifier whenever current measurement data are not available at said upstream optical amplifier.

26. A control loop for an optical amplification span of a wavelength switched optical network comprising:

means for measuring at preset intervals, a set of performance data regarding a WDM signal traveling along an optical section;

a vector gain loop for receiving a set of current performance data and a gain target, and providing a gain adjustment signal comprising a gain adjustment component for each channel of said WDM signal;

a control rules block for processing said gain adjustment components according to said set of current performance data, a set of previous performance data and section status data, and providing a control signal;

wherein said control signal adjusts the operational parameters of all card-packs of said optical section to provide substantially similar output power for each channel of said WDM signal.

27. A control loop as claimed in claim 26 wherein said control rules block comprises a model of said optical section and wherein said model is continuously updated according to said set of current performance data and status data.

28. A control loop as claimed in claim 26, wherein said optical section encompasses a fiber span characterized by a fiber loss, a Raman module characterized by a Raman gain, and an EDFA module characterized by an EDFA gain.

29. A control loop as claimed in claim 28, wherein said control rules block provides for lowering said Raman gain whenever said fiber loss decreases, to maintain a net gain.

30. A control loop as claimed in claim 28, wherein said control rules block provides for maintaining said Raman gain and decreasing the power input to said optical section to maintain said net gain, whenever said optical section has a low loss.

31. A control loop as claimed in claim 28, wherein said control rules block provides for decreasing said Raman gain and decreasing the power input to said optical section to maintain said net gain, whenever said optical section has a low loss.

32. A control loop as claimed in claim 26, wherein said control rules block provides a gain target for an upstream optical amplifier whenever said set of current performance data is not available at said upstream optical amplifier.

33. A control loop as claimed in claim 26, wherein said control rules block provides for in-building loss compensation.

34. A control loop as claimed in claim 33, wherein said in-building loss compensation is performed first as a bulk network wide optimization and next as a detailed, site-specific optimization.

35. A method of transmitting a WDM signal along a span of a wavelength switched optical network comprising:

measuring an input power of said WDM signal at the input of said span;

amplifying said WDM optical signal and measuring the spectrum and output power of said WDM signal; and

controlling operation of said optical amplifier according to said input and output power and spectrum and also according to a set of rules to compensate for the losses and degradation of said WDM signal along the fiber of said span.

36. A method as claimed in claim 35, wherein said step of controlling is effected at regular intervals for continuously optimizing transmission along said span in the presence of dynamic configuration and re-configuration of connectivity within said wavelength switched network.

37. A method as claimed in claim 35, wherein said step of amplifying comprises amplifying said WDM signal with a Raman gain, further amplifying said WDM signal with an EDFA gain and flattening the spectrum of said WDM signal with gain flattening means.

38. A method as claimed in claim 37, wherein said step of amplifying said WDM signal with a Raman gain comprises:

determining a maximum provisioned Raman gain value *G_raman_max*, where a loss parameter is acceptable for a set of channels of said WDM signal;

reducing said Raman gain from said maximum gain value to a flexed gain value *G_raman = G_raman_max – (Mean_span_loss – Actual_span)*, while keeping said EDFA gain unchanged, for enhancing said loss parameter of under-performing channels of said WDM signal; and

pumping light along said span to obtain said *G_raman*.

39. A method as claimed in claim 38, further comprising providing an offset and adjusting said flexed gain to *G_raman = G_raman_max – (Mean_span_loss – Actual_span) + Offset.*

40. A method as claimed in claim 37 wherein the *Mean_span_loss* is selected for a large range of fiber types.

41. A method as claimed in claim 38, wherein said step of determining comprises:

during network commissioning, determining maximum provisioned Raman gain for a link to which said span belongs;

setting-up all said Raman gain for each optical amplifier along said link to said respective maximum provisioned Raman gain value;

noise loading said link until a measurable Q/BER value is achieved at the output of said link;

adjusting said maximum provisioned Raman gain value of each said optical amplifier until an optimum Q is achieved for said link.

42. A method as claimed in claim 41 further comprising tilting said Raman gain to equalize and minimize a noise parameter for all channels in said WDM signal.

43. A method as in claim 42, wherein said step of tilting comprises changing the ratio of the power provided by the pumps of each said respective pump unit.

44. A method as claimed in claim 38, wherein said step of amplifying comprises setting said Raman gain at a level above a maximum provisioned gain; and reducing said EDFA gain for a set of blue channels at the border of the L-band for obtaining a reduced spectrum for said optical amplifier to allow

operation of said wavelength switched optical network in both C-band and L-band.

45. A method as claimed in claim 44, further comprising specifically attenuating said set of blue channels using gain flattening means.